ARMY RESEARCH LABORATORY

Modeling of Atmospheric Effects

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Realistically modeling atmospheric effects and their impacts is a difficult task. Atmospheric effects run the gamut from small scale, localized effects such as thundershowers, fog, smoke, etc., to large-scale synoptic events such as weather fronts. Once these features are modeled they must then be correctly applied and/or interfaced with other, usually larger, simulations. To avoid duplicative efforts it is prudent to establish standards in various areas. The Dynamic Atmospheric Environments (DAE) category is one of twenty areas established by the U.S. Army's Modeling and Simulation Office to set standards in the area of atmospheric modeling. This document provides the definition, requirements, objectives and roadmap for the DAE category. Also presented are those efforts that are currently underway in the U.S. Army that have as their goal to render more atmospheric realism in models and simulations in order to ultimately provide the Commander and soldier with more accurate choices or predictions on the battlefield.

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Preface

This document provides a summation of ongoing and recent developments in the Army Modeling and Simulation Office's category of Dynamic Atmospheric Environments. The determination of standards is a cost effective reuse of existing resources. Therefore included herein is a brief explanation of the Army Model Improvement Plan and the definition, requirements, and objectives of the standards category of Dynamic Atmospheric Effects.

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Executive Summary

The battlefield environment includes many sources of aerosols and particulates such as chemical and biological agents, smoke, dust, fog and chaff. These add to the natural environment increasing the presence of non-uniform aerosol regions. Weather, atmospheric transport and diffusion processes, and the attenuating effects of the environment on the propagation of electromagnetic energy all impact target acquisition and high-technology weapons. The atmosphere and clouds provide cues, alter target and background signatures, and produce scene clutter both in the real world and in realistic computer-generated simulations. All these weather effects and impacts are in the Dynamic Atmospheric Environments (DAE) domain and are in harmony with the Department of Defense objective representation of the atmosphere.

Due to the dynamic range of atmospheric processes, the DAE category must represent a requirement spectrum ranging from small-scale effects found in high-resolution models, such as scene visualization, to large-scale, low-resolution, aggregated effects, to correctly represent weather impacts. In the high-resolution area physics-based calculations, such as the Weather And Visualization Effects for Simulations, are needed to represent high fidelity natural and battlefield-induced atmospheric. At the other end of the spectrum are the high-level simulations that deal with aggregated units. These simulations simply cannot afford to include detailed calculations for individual platforms and systems. Thus, a new approach is needed to include weather at a realistic level of fidelity and still maintain "faster than real time" simulation capability. Such an approach may exist in using rule-based programs such as the Integrated Weather Effects Decision Aid. DAE requirements, presented in priority order, are:

1. to provide fundamental environmental models for modeling and simulation (M&S),

2. identify requirements for standard atmospheric scenarios,

3. provide methodologies for determining consistent data sets for environmental effects models, and

4. provide standardized databases for system performance analysis.

In concert with these requirements, the DAE category has the objectives of identifying fundamental gaps in atmospheric M&S, ingesting live

meteorological data and real-time forecasts into simulations. Additional objectives include the development of:

- fundamental dynamic environment databases to support M&S,
- standard synthetic natural environment scenarios and backgrounds, and
- standard tools to facilitate weather impact decision aids and system performance analyses.

Models that currently exist or are under development leading towards standards in the DAE category, such as the modeling of the ground state in winter environments, light scattering for war games and target acquisition, and three-dimensional static environments and initialization are presented here. Progress relevant in the DAE category is also presented in the areas of: weather tactical decision aids, such as the rule-based Integrated Weather Effects Decision Aid, the physics-based Target Acquisition Weather Software, and acoustic decision aids (Acoustic Battlefield Aid and Battlefield Acoustic Sensor Evaluator); live and synthetic weather to include the Battlefield Forecast Model, the fielded Integrated Meteorological System, and microscale modeling High Resolution Wind (HRW); transport and diffusion models (Second Order Closure Integrated PUFF [SCIPUFF], Vapor Liquid Solid Tracking [VLSTRACK], Two-Dimensional Transport and Diffusion for Personal Computers [D2PC], and Transport and Diffusion Simulator [TADSIM]); acoustic (Scanning Fast-Field Program [SCAFFIP], and Scanning Parabolic Equation [SCAPE]), electro-optical propagation (Weather and Visualization Effects for Simulations [WAVES], Atmospheric Optical Turbulence Model [ATMOS], and Electro-Optical Systems Atmospheric Effects Library [EOSAEL]); atmospheric optical turbulence (CN2); backgrounds (Smart Weapons Operability Enhancement [SWOE], Computer Generation of Realistic Environments with Atmospheres for Thermal Imagery with Optics and Noise [CREATION]); and other efforts (virtual dirty battlefield and clutter statistics).

1.0 Introduction

The Department of Defense (DoD) Modeling and Simulation (M&S) Master Plan [1] currently has six objectives, shown in table 1, which form a framework within which standards development proceeds. In order to support these six DoD objectives the Army Modeling and Simulation Master Plan [2] introduced and defined the standards development process and established the role of standards category coordinators within the Army. These 19 categories annually provide the Army Modeling and Simulation Office (AMSO) a report in their area on the status of standardization, significant progress during the past year, and standardization priorities for the next year. One of these 19 standards categories is the category of Dynamic Atmospheric Environments (DAE). Definitions, objectives, ongoing work, and the status of the DAE category are presented here.

Table 2: DoD M&S Objectives

DoD M&S Objectives
• Develop a common technical framework for M&S
• Provide timely and authoritative representations of the natural environment
• Provide authoritative representations of systems
• Provide authoritative representations of human behavior
• Establish a M&S infrastructure to meet developer and end-user needs
• Share the benefits of M&S

In today's climate of reduced funding and decreasing budgets, it is imperative that models are reused and standards developed. This is particularly true in the DAE area since simulation of military operations must include realistic representations of the natural environment. However, a simulation attempting to emulate the real world around us is only as good as the computer models within it. To effectively model the atmosphere within variable simulation contexts is a formidable task. Atmospheric effects range from small-scale effects, such as smoke plumes and turbulence, to large-scale synoptic systems. These effects must be dealt with from detailed simulations that require physics-based models to high-level aggregated simulations that require a "broad brush" outlook and cannot afford the computational burden of detailed models.

2.0 Army Model Improvement Plan

The Army Model Improvement Plan (AMIP) supports the technical M&S standards development goals of the U.S. Army by investing in M&S projects that will lead to standard algorithms, data, procedures, techniques, etc. Each fiscal year, Army Standards Category Coordinators (SCC), as designated in the U.S. Army M&S Master Plan, nominate M&S projects that will further standards development objectives within their respective standards categories. Projects are selected for funding each year based on their potential contribution. AMIP program goals are to:

- further standards development objectives within each category,
- address Army specific problems, and
- make use of existing R&D models.

M&S organizations nominate projects focused on the AMIP Program goals. The nominations are selected and prioritized by the appropriate standards category team. All projects submitted by each SCC are considered by the Policy and Technology (P&T) Working Group (WG), which prioritizes them for the Army Modeling and Simulation Executive Committee (AMSEC) review. The criteria used by the P&T WG to evaluate the various AMIP proposals are:

- degree to which a proposal addresses the objectives of the proposing standards category;
- applicability across and acceptance by the U.S. Army M&S community; and
- feasibility, technical risk, and management risk associated with the project.

Once reviewed by the AMSEC and approved by the Deputy Undersecretary of the Army for Operations Research, projects are funded according to their priority and available funds. Projects may be funded over multiple years, but must compete each year against all other projects submitted for funding that year. The AMIP program is managed by AMSO. DAE AMIP funded projects for FY 98 and 99 are presented in this report.

3.0 DAE Standards Category Definition

The DAE category for U.S. Army M&S includes those objects, algorithms, data and techniques required to replicate weather, weather effects and impacts, backgrounds, acoustics, and transport and diffusion (T&D) of aerosols and battle by-products.

The battlefield environment includes many sources of aerosols and particulates such as chemical and biological agents, smoke, dust, fog and chaff. These add to the natural environment increasing the presence of non-uniform aerosol regions. Weather, atmospheric T&D processes, and the attenuating effects of the environment on the propagation of electromagnetic energy all impact target acquisition and high technology weapons. The atmosphere and clouds provide cues, alter target and background signatures, and produce scene clutter both in the real world and in realistic computer-generated simulations. All these weather effects and impacts are in the DAE domain and are in harmony with the DoD objective representation of the atmosphere.

The DAE category does not explicitly cover terrain, but it does cover weather influences on terrain. For example, snow cover will change the surface albedo; rainfall will alter the ground state affecting mobility. Atmospheric radiative transfer affects target and background signature propagation, illumination and diurnal heating, which will modify background signatures. All these effects fall under the purview of DAE. The exception is target signatures, which are handled in the domain of the standards category of Acquire, thus, highlighting the interconnectivity of standards categories.

4.0 DAE Standardization Requirements

The natural environment is important in determining the outcome of real battles. Included in this area are weather features (clouds, fronts, thunderstorms, etc.) and weather effects such as target contrast changes. Meteorological data and weather scenarios are becoming available through efforts such as the Defense Modeling and Simulation Office (DMSO) funded Weather Scenario Generator [3], the Master Environmental Library [4], and the Total Atmosphere and Ocean Server [5]. However, converting these meteorological parameters and weather features into quantitative effects and impacts that are not computationally burdening for simulations is a difficult proposition.

Due to the dynamic range of atmospheric processes, the DAE category must represent a requirement spectrum ranging from small-scale effects found in high-resolution models, such as scene visualization, to large-scale, low-resolution, aggregated effects, to correctly represent weather impacts. In the high-resolution area physics-based calculations, such as the U.S. Army Research Laboratory's (ARL) Weather And Visualization Effects for Simulations (WAVES) [6], are needed to represent high fidelity natural and battlefield-induced atmospheric effects (e.g., smoke, illumination, rain and fog, T&D, etc.) but usually are available only at a high computational burden. To reduce this burden a scenario-specific natural environmental representation can be pre-computed or pre-scripted (if time-varying) for later real-time simulations. However, embedded environmental processes include battlefield-generated clouds, from munitions, vehicles, agents and fires, whose location and time of introduction cannot be completely pre-scripted. They are event driven, resulting from battle actions and combatant decisions, and thus, can only be partly precomputed. These processes are embedded into the natural aerosol environment and are generally more localized and dynamic than other battlefield effects. Atmospheric parameters and effects from embedded processes are thus both super-imposed on and affected by input conditions described by the natural environment representation. In some cases, the environmental embedded processes will be the dominant factors in determining the outcome of a simulation.

While progress has been made in representing atmospheric effects, notably in the Defense Advanced Research Projects Agency Synthetic Theater of War–Synthetic Environments (STOW-SE) program [7], such efforts require dedicated hardware and precomputed weather effects

scenarios. The underlying models in these simulations are inherently computationally intensive. Engineering level line-of-sight propagation models from ARL's Electro-Optical Systems Atmospheric Effects Library (EOSAEL) [8] and the Air Force Research Laboratory's Moderate Resolution Transmission (MODTRAN) [9], while fast, are still burdensome considering the playing area, the potential number of lines-of-sight between entities and the number of pixels needed to generate virtual scenes.

High-level simulations that deal with aggregated units simply cannot afford to include detailed calculations for individual platforms and systems. Thus, a new approach is needed to include weather at a realistic level of fidelity and still maintain "faster than real time" simulation capability. Such an approach may exist in using rule-based programs, such as ARL's Integrated Weather Effects Decision Aid (IWEDA) model [10]. This model, based in Army doctrine, provides color-coded matrix charts showing the impact weather has on various platforms, sensors, and weapons systems thereby allowing for simple and fast assessments over large areas without a heavy computational burden. In order to provide for these disparate needs (of both high- and low-resolution simulations) DAE requirements, presented in priority order in table 2, are general in nature.

Table 2. DAE Requirements

DAE Requirements
• Provide Fundamental Environmental Models for M&S
• Identify Requirements for Standard Atmospheric Scenarios
• Provide Methodologies for Determining Consistent Data sets for Environmental Effects Models
• Provide Standardized Databases for System Performance Analysis

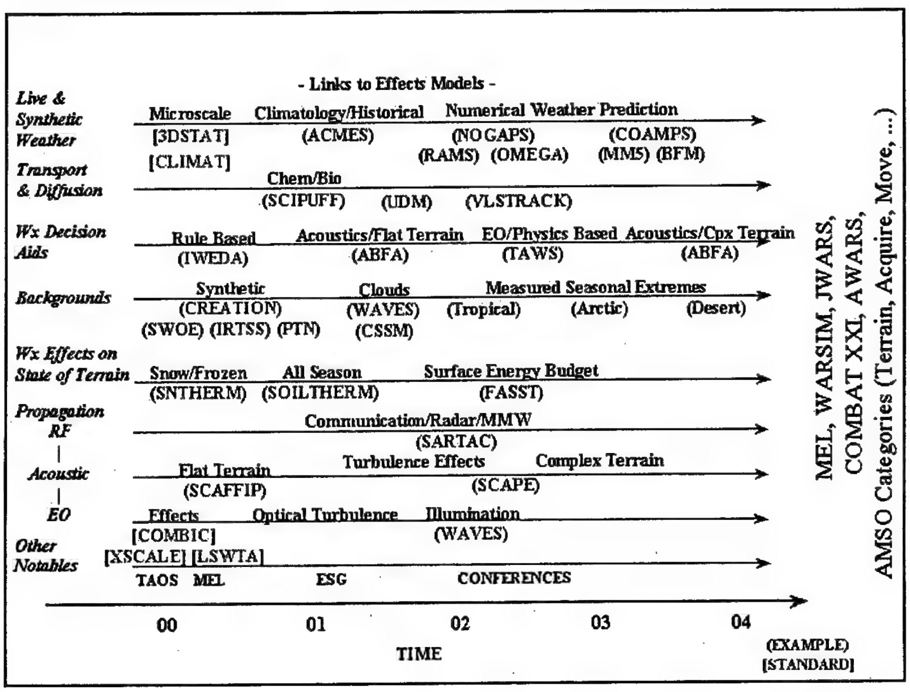
5.0 DAE Objectives

In concert with these requirements, the DAE category has the objectives of identifying fundamental gaps in atmospheric M&S, ingesting live meteorological data and real-time forecasts into simulations. Additional objectives include the development of:

- fundamental dynamic environment databases to support M&S,
- standard synthetic natural environment scenarios and backgrounds, and
- standard tools to facilitate weather impact decision aids and system performance analyses.

Models that currently exist or are under development that will satisfy these objectives are embodied in the DAE category roadmap (see figure 1).

Figure 1. DAE roadmap



6.0 DAE Assessment and Accomplishments

6.1 Assessment

Modeling efforts leading to the development of standard algorithms in the DAE area are, as might be expected, strong in some areas and in need of additional effort in others. In FY99, three EOSAEL models were approved as standards in the DAE category:

1. the climatology (CLIMAT) model [11],

2. the aerosol propagation model scaled transmission (XSCALE) [12], and

3. the smoke model Combine Obscuration Model for Battlefield Induced Contaminants (COMBIC) [13].

DAE AMIP projects, which include the FY98 Modeling of the Ground State in Winter Environments and the FY99 Light Scattering for Wargames and Target Acquisition and Three-Dimensional Static Environments and Initialization (3DSE), are discussed below along with other additional areas where progress has been made this past year.

Teaming arrangements for the Dynamic Atmospheric Environments category include members from ARL, the Army Space and Missile Defense Command, the Cold Regions Research Engineering Laboratory (CRREL), and the AMTEC Corp.

6.2 Accomplishments

6.2.1 Modeling of the Ground State in Winter Environments

6.2.1.1 Objective

Cold environments can have drastic effects on U.S. Army operations. Current available U.S. Army models and simulations have almost no ability to replicate these effects. An inaccurate forecast, or no forecast at all, of the impact of cold environments on Army operations can have a negative effect on training, resulting in inaccurate planning, faulty analysis and subsequent failure of U.S. Army operations. The objective was to address the issue of predicting the state of the ground (surface temperature, snow cover, snowmelt, and freeze and thaw depths) by utilizing CRREL's snow thermal (SNTHERM) energy balance model. The methodology investigated the sensitivity of the ground state to different

flux model initializations, including a semi-empirical model, a plane parallel model, and ARL's Atmospheric Illumination Module (AIM). Model runs for two locations (Grayling, Michigan and Yuma, Arizona), three seasons (spring, fall, and winter), and three sky states (clear, partly cloudy and cloudy) using the three flux model initializations and measured data have been made. The results were inter-compared including a comparison with measured ground state information.

6.2.1.2 Background

It is a well-established fact that the state-of-the-ground is driven in a large part by downwelling solar and infrared (IR) fluxes. Models developed to predict the state-of-the-ground for U.S. Army operations depend critically on these fluxes for initialization. Unfortunately, these fluxes are not routinely measured parameters as is the case with more common meteorological parameters like temperature, relative humidity, etc. Therefore, indirect methods must be utilized to generate the required flux initialization information for state-of-the-ground models. Predicted ground temperatures were compared by using the Smart Weapons Operability Enhancement Thermal (SWOETHERM) model initialized with different solar flux schemes. These initialization schemes used solar flux values measured during the Smart Weapons Operability Enhancement (SWOE) [14] field programs, and calculated solar flux values from Shapiro's semi-empirical model, a plane parallel model (MODTRAN), and ARL's AIM Model [15].

Variations in the level of spatial and temporal variability in the surface temperature and solar loading represent clutter. This clutter can degrade the performance of weapon systems. The performance impact on infrared systems is a direct consequence of this variation in the surface temperature and this variability affects systems operating in other spectral regions. For example, variations in the solar loading can cause variations in the physical characteristics of snow that can have a significant effect on active radar systems. With the recent emphasis on distributed models for synthetic scene generation, and the development of segmentation techniques that facilitate the distributed use of one-dimensional (1-D) models, it is imperative that models are developed to provide the spatial and temporal variability of environmental parameters that drive the energy budget models used to predict the state-of-the-ground.

6.2.1.3 *Results and Findings*

The response of the surface temperature to different solar flux initialization schemes was investigated keeping all other environmental parameters constant. It was determined that for clear skies all schemes resulted in nearly identical surface temperatures. Thus, a semi-empirical model like Shapiro's has the advantage of computational speed. For partly cloudy and cloudy skies, only the AIM model mimicked the spatial variability observed with the solar flux and the resulting spatial variability in the surface temperature. The Cloud Scene Simulation Model (CSSM) [16] was used to determine the spatial variability of the clouds. The cloud distributions were then used by AIM to produce the variations of the surface solar loading. CSSM also has the capability to produce the temporal variations in the cloud fields for short periods of time. Thus, it would be possible to use CSSM and AIM to produce the temporal and spatial variations in the solar loading. Models like AIM frequently incur a large computational burden. In order to reduce the computational burden associated with AIM several new procedures were implemented and investigation of additional techniques that can be used to reduce the model runtime will be continued. Distributed energy budget models used to predict the state-of-the-ground for the virtual depiction of the battlespace require distributed environmental parameters for initialization. Many of these parameters can be obtained from mesoscale models like Fifth-Generation National Center of Atmospheric Research /Penn State Mesoscale Model (MM5) or databases associated with programs like the Integrated Meteorological System. However, none of these models or programs provides distributed solar or IR flux, a key initialization parameter of energy budget models. Models like AIM linked to CSSM, or for that matter any model that provides information on the spatial and temporal distribution of atmospheric conditions, can be used to provide the spatial and temporal distribution of radiative fluxes. In addition to exploring techniques to decrease the run time of AIM, the potential use of AIM to generate distributed infrared fluxes should be explored.

Based on the measured solar flux and surface temperatures from the Yuma, Arizona SWOE field program, it was found that the surface temperature for this semi-arid climate varied by several degrees for two measurement sites separated by approximately 100 m for partly cloudy skies. The measured solar fluxes varied by a factor of up to two, depending on the cloud conditions. Similar variations occurred during the Grayling, Michigan field programs. A surface temperature change of

approximately 4 °C over a period of approximately 12 min was recorded at a single site during the Yuma, Arizona field program. The corresponding change in the total solar flux was approximately 500 W/m^2. Overcast sky conditions also produced similar variations in the surface temperature and the total solar flux. These variations were attributed, in part, to variations in the cloud thickness (cloud optical depth). Thus, under most sky conditions, variations in solar loading were shown to produce spatial and temporal variations in temperature which influences IR signatures of background features.

6.2.2 Light Scattering for War Games and Target Acquisition

Light scattering from atmospheric aerosols affects the ability of a sensor operating in the visible to acquire targets. This effect, also known as path radiance, is embodied in wargames and target acquisition models as the sky-to-ground ratio (SGR). The SGR can vary from 0.2 for snow to 25 for forested conditions; accurate SGR determinations are needed to assure a high confidence for target acquisition ranges used in wargames and test and evaluation.

The AMSO standards category of Acquire has requested a standard code. To accomplish this, Combined Arms and Support Task Force Evaluation Model's (CASTFOREM) [17] legacy is being compared with the AIM research grade code. A new model is being developed by extracting relevant portions from the legacy models and incorporating these with improvements determined from the research grade code and advances in the literature. This will result in a final model with fewer limitations and improved accuracy. This model, along with documentation, will be provided to U.S. Army Training and Doctrine Command Analysis Center. Potential also exists for application to Night Vision and Electronic Sensors Directorate's sensor performance model, Acquire [18]. The final model will also be proposed as a standard in the standards categories areas of DAE and Acquire.

6.2.3 Three-Dimensional Static Environments and Initialization

The operational U.S. Army operates in a four-dimensional (4-D) environment. This places upon the modeling community a need to provide simulations in a spatially realistic three-dimensional (3-D) environment. Typically, the source of environmental data such as temperature, wind speed and direction, humidity and level of turbulence

is a database, which generally contains values at a point or perhaps along a line. Such information is not adequate to realistically portray the environment, its variability, or its effects. This effort will improve and combine existing techniques/models to produce a complete static 3-D description of the environment based on input from typical data sources.

7.0 Other Army Efforts

7.1 Weather Tactical Decision Aids

Weather tactical decision aids (TDA)s come in two flavors: rule-based and physics-based. Rule-based TDAs are constructed though rules that have been collected from field manuals, U.S. Army Training and Doctrine Command (TRADOC) centers and schools, and subject matter experts. Physics-based TDAs employ physics calculations that have their basis in theory or field measurements.

7.1.1 Tri-Service Rule-Based Weather Tactical Decision Aids

The U.S. Army's Integrated Weather Effects Decision Aids is being adopted as the model for rule-based weather impact decision aids for all the services. A rule-based decision aid provides a general framework based on lists of "if-then-else" rules and pre-established critical weather thresholds for moderate or severe impacts. The U.S. Air Force, U.S. Navy and U.S. Army, with concurrence from the U.S. Marine Corps, are now collecting weather impacts using this common format and the current database of hundreds of rules are expected to expand to several thousands of rules. The U.S. Army IWEDA is designed for the Army Common Hardware/Software and the Defense Information Infrastructure Common Operating Environment as part of the Integrated Meteorological System (IMETS); the Command, Control, Communications, Computers and Intelligence (C4I) weather system IS currently fielded and being improved for the U.S. Army First Digitized Division.

7.1.1.2 The Integrated Weather Effects Decision Aid

The IWEDA is a rule-based weather impact model based on U.S. Army doctrine. IWEDA allows for simple and fast assessments over large areas of weather impact factors on units based on their types of platforms, sensors, and weapons. IWEDA provides this information to the U.S. Army's tactical C4I systems in the form of red-amber-green (unfavorable/marginal/favorable) 3-D (x, y, time) data grids and as common-map overlays. IWEDA is an integral part of IMETS.

IWEDA is being proposed as the basis for a Joint service rule-based tactical decision aid by the U.S. Army Intelligence Center. IWEDA includes U.S. Army, U.S. Air Force, U.S. Navy and limited threat systems.

Not only is information provided on sensor systems and platforms but also on other effects of weather, such as impacts on deployment of ground-staked antennas due to wind conditions or temperatures too cold for diesel vehicles to start. IWEDA generates simple red-amber-green tables and overlays with a short text message describing the weather impact. The colors highlight the potential for reduced effectiveness.

IWEDA's approach differs from a physics-based approach insofar as it is based on a large number of weather impact "rules". Each system has its list of relevant rules, and each rule definition includes red-amber-green "critical value thresholds" for one, or a combination, of the meteorological parameters that affects the system. These weather impact rules and critical values have been validated through TRADOC organizations, field manuals and National Ground and Intelligence Center for the various systems. IWEDA also includes an interactive rule editor that allows the user to easily modify rules and critical values.

ARL is in the process of coupling IWEDA's rule-based weather impacts with information from physics-based tactical decision aids in order to provide required performance factors and probabilities applicable to aggregated simulations. This effort will then be able to support faster than real-time simulation for more efficient play of weather and at a fidelity comparable to that used in aggregate simulations.

7.1.2 Tri-Service Physics-Based Weather Tactical Decision Aids

Physic-based tactical decision aids, as distinct from rule-based decision aids, perform detailed performance calculations for specific systems. Tri-service models for electro-optic propagation, such as the Tri-Service Target Acquisition Weather Software (TAWS) and models for acoustics, are being linked to rule-based TDA's to provide more detailed effects and quantitative information.

7.1.2.1 Target Acquisition Weather Software

The Tri-Service Target Acquisition Weather Software (TAWS) and its predecessor, the U.S. Air Force's Electro-Optical Tactical Decision Aid (EOTDA), are software models that predict the performance of weapon systems and direct view optics based on environmental and tactical information. The U.S. Army's TDA, target acquisition (TARGAC), is a variant of EOTDA. Performance is expressed primarily in terms of

maximum detection, recognition, or lock-on range. The EOTDA and TARGAC supported systems in three regions of the spectrum:

1. visible/TV (0.4 to 0.9 μm),
2. Laser (1.06 μm), and
3. far IR (8.0 to 12.0 μm).

TAWS extends this to include the mid-IR (3.0 to 5.0 μm).

TAWS consists of three essential parts:

1. an inherent-target contrast model,
2. an atmospheric effects model, and
3. a system performance model.

These basic models are required for any type of device treated by TAWS; however, the nature of the models that perform a given function may vary considerably depending on the system of interest. For example, the inherent contrast for visual and television devices depends on the relative reflectances of the target and background. Thus, atmospheric scattering and solar illumination [19] are overriding factors. For thermal imagers, the inherent contrast consists of the difference in temperature between the target and background. Solar loading is the dominant factor thus requiring access to previous and forecast conditions required by the thermal balance model [20,21]. The nature of the calculations of atmospheric propagation is also different in the visual than in the IR. Scattering primarily influences the former, while the latter is dominated by absorption. The U.S. Army Model and Simulation Office standards category model Acquire is used for sensor performance. TAWS will also allow for automated meteorological ingest via the Air Force Weather Information Network; these meteorological variables may be selected or changed through numerous Graphical User Interfaces.

7.1.3 *Acoustic Decision Aids*

The Acoustic Battlefield Aid (ABFA) is ARL's prototype acoustic decision aid tool developed under MATLAB®. ABFA performs realistic calculations of probability of detection, direction-finding resolution, spatial resolution from acoustic array networks, and other sensor performance metrics relevant to U.S. Army applications. It demonstrates ARL's unique capability to assess environmental effects on U.S. Army acoustical systems. ABFA also incorporates turbulence effects on acoustic sensors in addition to a simple model for the effects of terrain.

The developments being made in ABFA are being transitioned to the Battlefield Acoustic Sensor Evaluator (BASE) (see section 7.4.1).

7.2 Live and Synthetic Weather

Various numerical weather prediction models of interest to the U.S. Army are being compared using common initialization and ground-truth data sets. The U.S. Army's Battlescale Forecast Model (BFM) [22], U.S. Navy's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) [23], U.S. Air Force's MM5 [24], Colorado State University's Regional Atmospheric Modeling System (RAMS) [25], and other specialized weather forecasting models are being compared by ARL's Battlefield Environment Division. By using common inputs and for comparison against actual weather, the U.S. Army will be able to identify which models are best under various meteorological conditions and hardware/software constraints.

7.2.1 The Battlefield Forecast Model

ARL's BFM is the U.S. Army's mesoscale model and, as such, is a proposed DAE standard. BFM is a meteorological forecasting model that is used primarily to obtain 4-D meteorological field parameters (e.g., winds, temperature, moisture, cloud, turbulence parameters, etc.) over complex terrain. The BFM is currently resident on the U.S. Army's fielded IMETS. The strength of the BFM comes from the high resolution of the model (10 km) and its ability to incorporate terrain effects. This gives the forecaster in the field a quick understanding of the effects the local battlefield terrain will have on the weather.

The BFM, a hydrostatic, quasi-Boussinesq, 16-layer mesoscale model, is initialized with real-time data and forecasted results from a synoptic-scale model. It consists of several elements including a terrain elevation data production program, a three-dimensional (3-D) data analysis program of input data for model initialization and data assimilation, and a prognostic mesoscale model, called the Higher Order Turbulence Model of Atmospheric Circulation. As part of BFM model output, interpolation programs for horizontal and vertical displays at desired heights and grid locations, graphical user interfaces for data input, execution, and display of the meteorological forecast are provided. A map background server to ease visualization of execution and forecast field display, and a series of algorithms in the Atmospheric Sounding

Program to forecast visibility, clouds, icing, turbulence, etc. are also available.

7.2.2 *The Integrated Meteorological System*

The IMETS is the meteorological component of the Intelligence and Electronic Warfare element of the Army Battle Command System (ABCS). IMETS provides commanders at all echelons with an automated- weather system to receive, process, and disseminate weather observations, forecasts, and weather effects decision aids to all Battlefield Functional Areas (BFA)s.

IMETS will have three configurations:

1. a command post configuration with IMETS permanently integrated into the local area network;

2. a vehicle mounted configuration for tactical operations where the supported echelon moves; and

3. a light configuration, integrated into a small task force, where light weight, easily deployed, core weather functions can be performed without having a separate vehicle to shelter the system.

Each configuration provides automation and communications functions to support Staff Weather Officers assigned to echelons from Separate Brigades and higher, and to U.S. Army Special Operations Forces.

IMETS receives weather information from meteorological satellites, the Air Force Weather Agency, artillery meteorological teams, remote atmospheric sensors, and civilian forecast centers. IMETS then processes and distributes weather forecasts, observations, and climatological data to produce timely and accurate weather products designed to the meet the specific war fighter's needs.

The U.S. Army's BFM and the U.S. Air Force's mesoscale models provide weather forecasts on the scale needed by the U.S. Army; these forecasts provide numerous weather parameters at 10 km resolution (higher resolution planned). High-resolution forecast data are made available to the Staff Weather Officer and other U.S. Army users via two-dimensional (2-D) and 3-D displays and IWEDA that displays weather effects on friend and enemy tactical systems.

Significant weather and environmental support for war fighters is found in the form of automated tactical decision aids, such as IWEDA, produced by the IMETS. These graphics go beyond briefing the weather. They display the impact of the weather on current, projected, or hypothesized conditions on both friendly and enemy capabilities. Instead of reacting to the weather, the war fighter can take advantage of the weather and the force multiplier of the effects of the weather can then be used by decision-makers for tactics and maneuver.

IMETS is critical to the war fighter's decision-making process because it provides data directly to many other force multipliers. The other BFAs in ABCS depend on IMETS to provide the following:

- near real-time data for safe aviation operations;
- the weather feature for the common tactical picture;
- landing/drop zone data for air assault/airborne operations;
- current and forecast weather for maneuver, artillery, intelligence and electronic warfare, air and missile defense, and combat service support planning;
- wind and atmospheric data for nuclear, chemical and biological planning;
- communications linkage from Army Common User System, Tactical Operations Center Local Area Network, weather satellites and forecast centers to contingency forces; and
- terrain mobility/counter mobility weather information.

IMETS provides first-in weather support to contingency forces, tailored weather information for deep fires and precision munitions, and weather effects decision aids for the planning and execution of maneuver and support activities.

IMETS actively participates in the Force XXI initiatives ensuring that IMETS is an integral part of the U.S. Army's digitization effort and that it will continue to meet the war fighter's needs into the 21st Century.

7.2.3 *Microscale Modeling*

The ARL developed High Resolution Wind (HRW) [26] model is a two-dimensional, diagnostic, time independent model which computes

horizontal fields of the wind components, the mean wind velocity, friction velocity, potential temperature, the Richardson number and the Power Law exponent. The model typically simulates the flow field over a gridded area of some 5 by 7 km with a spatial resolution of 100 m. Model initialization requires a single surface value of wind speed and direction, temperature, and a corresponding radiosonde type measurement. The radiosonde data is used to provide an estimate of the bulk atmospheric buoyancy. The model computes this estimate by applying the initial single point values at each grid point in the computational array, along with digitized terrain elevation. Simulation results are obtained by direct-variational relaxation of the wind and temperature fields in the surface layer. The solution is reached when the internal constraint forces imposed by the warped terrain surface, thermal structure, and requirements for flow continuity are minimized. The procedure uses Gauss' Principle of Least Constraints, which requires these forces to be minimized in order to satisfy the equations of motion. When applied to the surface layer, this procedure requires the use of empirical wind and temperature profiles. The computational domain size can range from 2 by 2 km to 20 by 20 km with grid resolutions of 40 to 400 m, respectively. Note that HRW is usually run for a nominal 5 by 5 km area and a vertical thickness of the computational layer 1/10th the magnitude of the grid size. This layer thickness can, however, vary from 2 to 50 m.

HRW includes the effects of canopies. The effect of vegetation to the overall Canopy-Coupled Surface Layer (CCSL) flow patterns is analogous to the effect of varying terrain heights. This approach to handling the effects of vegetative canopies on the flow has been quantified and validated against a number of field trials. Likewise, the canopy method for treatment of the urban domains does not include the effects of individual buildings but does provide the influence of the urban terrain on the large-scale flow. The CCSL technique allows the up-and-down scale linkage between flows from mesoscale weather models and flows in-and-around buildings. As an AMIP project (see section 6.2.3), these 2-D surface layer models are currently being extended to three dimensions. The original HRW model was designed to be viably operable on minimum input data. An improvement, which will provide the ability of the HRW model to be partially dynamic and be applicable to larger domains, has been initiated.

7.3 Transport and Diffusion

7.3.1 Second Order Closure Integrated PUFF

The Second Order Closure Integrated PUFF (SCIPUFF) model [27], which uses an internal second order turbulence closure scheme to improve the effects of local atmospheric effects on dispersion, has undergone additional validation by the Defence Threat Reduction Agency. The model, currently driven by interpolated data from large domain (mesoscale), is currently being linked by the FY99 AMIP project (3DSE) to surface layer wind models to increase the effects of terrain on near surface transport and to include the local effects of surface features on diffusion. This linkage will provide a very high (100 m) resolution capability for M&S T&D capability, but will not carry with it the normally high overhead associated with high-resolution meteorology. The integrated product will be available in FY00.

7.3.2 Vapor Liquid Solid Tracking, Two-Dimensional Transport and Diffusion Personal Computer and Transport and Diffusion Simulator

The U.S. Army supports three T&D modeling efforts. The approved operational models supported by the U.S. Army Chemical and Biological Defense Command is a Gaussian puff model, Vapor Liquid Solid Tracking (VLSTRACK) and D2PC (2-D T&D for Personal Computers). The D2PC model is the only model certified by the U.S. Army Nuclear and Chemical Agency for operational use. Both models use climatology and/or rudimentary meteorological parameterizations to compute the trajectory of a toxic cloud. VLSTRACK and D2PC are both easy-to-use programs that provide rapid results on personal computer type platforms. The primary causes for error in military applications of T&D models are inadequate source descriptions and the treatment of the spatial and temporal variability of dispersion. Data sets available for validation of dispersion models rarely contain adequate source information. The third model, ARL's T&D Simulator (TADSIM), is a suite of models which embodies a methodology to mitigate these problems and has been specifically designed to address the space and time variability issue.

VLSTRACK facilitates model initiation and output interpretation through its Graphical User Interface. However, the model is restricted due to its limited source term flexibility, the lack of terrain-influenced meteorology,

and its treatment of dispersion, which is tied to a limited categorization scheme. The source term selection is based on a library of delivery systems and agents. Inherent randomness in the mean flow, which in reality is a larger scale dispersion effect influenced by terrain, is driven by a random number generated functional variation to the transport. VLSTRACK comparisons with field trial data do not always agree. D2PC uses a single wind and turbulence parameter for the entire simulation domain and time period. Thus, this model can only be considered valid for flat terrain, small spatial domains, and short time intervals.

TADSIM consists of a transport driver utilizing 2-D wind fields at variable resolution and user-selectable codes for traditional Gaussian and non-Gaussian dispersion for both horizontal and vertical cloud spread. This suite of models is comprised of HRW (see 7.2.3); atmospheric simulation (AIRSIM), large eddy simulation (LES) model for airflow over terrain; airflow simulation (AIRFLOS), a LES model for airflow over structures; and an atmospheric chemical/biological simulation (ABCSIM), for T&D of the agent cloud. These dispersion codes are designed to be specific to the local meteorological and terrain conditions rather than using generalized classification techniques. TADSIM is in the verification/validation stage of development and employs a unique method for handling vertical diffusion called transilient turbulence. This technique is particularly suited to the treatment of dispersion in unstable atmospheres. The current version of TADSIM has been verified and has undergone limited validation.

7.4 Propagation

7.4.1 Acoustics

7.4.1.1 Scanning Fast-Field Program

The Scanning Fast-Field Program (SCAFFIP) [28] is an ARL atmospheric acoustics propagation model incorporating many of the effects of the environment on the sound field such as geometrical spreading, refraction, diffraction, molecular absorption, and complex ground impedance. It is based on the Fast-Field Program (FFP) with the added ability to scan multiple frequencies to predict the propagation conditions around the location of a sensor. The FFP is a one-way solution to the acoustic-wave equation originally developed for underwater sound propagation predictions. SCAFFIP calculates an attenuation table with range and frequency for a given geometry and meteorological profile. It

provides range estimations from the sensor or target for signal-noise of -10, -5, 0, and 10 dB (re: 20mPa) with azimuth for a given geometry, sound level of target at a given frequency, and meteorological profile. The meteorological profile and geometry provide the model the ability to calculate the sound-speed profile. The attenuation table is compatible for use by acoustic sensor performance models such as the Battlefield Acoustic Sensor Integration System (BASIS) and the BASE. BASE will be a versatile Unix-based acoustic decision aid the first version of which is under development and will be available by the end of FY00. The geometry profile is required because of the angular dependence of the sound speed; that is, the wind direction is related to the direction of propagation. This model works well over a flat-earth and a non-turbulent atmosphere. In the near future this model will be added to the EOSAEL.

7.4.1.2 Scanning Parabolic Equation

The Scanning Parabolic Equation (SCAPE) model is an atmospheric acoustics propagation model incorporating the same effects as SCAFFIP. It is based on the Green's Function Parabolic Equation (GFPE) with the added ability to scan multiple frequencies to predict the propagation conditions about the location of a sensor. The GFPE is a reformulation of the Split-Step Parabolic Equation model used in underwater acoustics. SCAPE is currently under development by ARL with the first version due in FY00. SCAPE will also calculate an attenuation table with range and frequency compatible with the sensor performance models such as BASIS and BASE. This model will allow for the incorporation of turbulence and terrain effects (see figure 2). Scattering from atmospheric turbulence will enhance signal levels at acoustic sensors located in refractive shadow zones where very low signal levels are expected. A version of the model including turbulence will be available by the end of FY00.

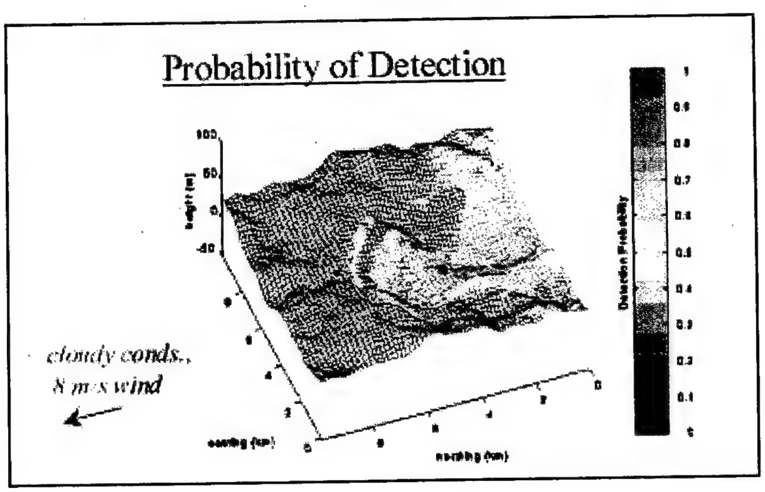


Figure 2. Probability of detection for a fixed, ground-based sensor (circle).

7.4.2 *Electro-Optical*

7.4.2.1 *WAVES*

The WAVES suite of models, being developed by ARL, predicts illumination and radiance information for a three-dimensionally variable atmosphere as a function of cloud type and amount, including partly cloudy skies at visual and IR wavelengths. It also predicts electro-optical propagation effects for horizontal and slant paths through the natural atmosphere. WAVES output illumination and propagation effects are critical to accurate target acquisition and scene generation. WAVES computations include direct solar/lunar radiation, multiply scattered solar/lunar radiation, optical turbulence, and forward scattering due to atmospheric aerosols.

WAVES was conceived and developed under a series of Tri-Service Programs to develop complete modeling and simulation of visualization and imaging of the atmospheric environment. WAVES beginnings may be traced to the SWOE program, through the Target Acquisition Modeling Improvement Program (TAMIP), the DMSO Environmental Effects for Distributed Interactive Simulation (E2DIS) program, and is now under the DSMO Executive Agent for Space and Atmospheres program "Radiometric Validation of the Cloud Scene Simulation Model (CSSM) and Boundary Layer Illumination and Radiative Balance Model (BLIRB)" where it is currently being integrated and evaluated.

The WAVES suite of models, (radiative transfer model BLIRB, atmospheric optical turbulence model (ATMOS), geometric radiance interpreter module View Point (VIEW), and the scene modifier module Pixel Modification (PIXELMOD) are integrated together to provide either modifications to existing scenes for real-time computer image generation or radiance values for a defined scenario. WAVES computes tables of solar and lunar multiply scattered radiation under varying atmospheric conditions that includes calculations for Rayleigh scattering, scattering by background aerosols, and scattering from inhomogeneous clouds and partly cloudy skies. WAVES does not attempt to impose any particular rendering method, but does provide the 2 and 3-D data to support a wide range of possible user implementations.

WAVES is being integrated with the Total Atmosphere Ocean Server (TAOS). This integration will allow High-Level Architecture (HLA) federations to have an ability to access the complex 3-D data produced by

WAVES. Integration with TAOS will also demonstrate that the application program interfaces being developed are sufficient to allow alternate HLA interfaces.

Additional ongoing work is evaluating detectability of biological aerosol clouds in near-, mid-, and far-IR wavebands. This has required creating a high-spectral resolution aerosol optical properties database for use in WAVES. This additional data will also be available for hyperspectral and other analysis.

In collaboration with Night Vision, a Tri-Service team is extending the capabilities of WAVES and MODTRAN for seamless integration of cloud and smoke effects for IR simulation. This work is aimed at providing capabilities for real-time IR scene simulation and rendering for realistic simulations and scene generation to allow development and testing of aided target recognition algorithms in different weather conditions. This will aid Night Vision's *Paint-the-Night* program and support modeling of solar loading for physics based thermal background clutter and target modeling.

The Information Science and Technology Directorate of ARL is integrating cloud field, illumination, and visibility results from the WAVES suite of models with their Future Tactical Operations Center research program. This integration will be used to explore how these tools can be used by commanders to better understand the battlefield and possible environmental impacts on their missions. Additional research will be performed to examine different styles of presentation and their effectiveness.

7.4.2.2 The Electro-Optical Systems Atmospheric Effects Library

The EOSAEL, developed by ARL, began its development in 1978 and is currently considered a mature code. EOSAEL contains 22 computer modules that can be separated into eight generic classes:

1. atmospheric transmission and radiance (low resolution transmission [LOWTRAN], ultraviolet transmission [UVTRAN], and near-millimeter wave [NMMW]);

2. laser propagation (laser transmission [LZTRAN] and non-linear vaporization and breakdown effects [NOVAE]);

3. tactical decision aids (cross wind integrated concentration [KWIK], grenade [GRNADE], helicopter [COPTER], and missile plume [MPLUME]);

4. battlefield aerosols (COMBIC and fire-induced transmission and turbulence effects [FITTE]);

5. natural aerosols (XSCALE and CLIMAT);

6. TARGAC;

7. radiative transfer (overcast [OVRCST], illumination [ILUMA], fast algorithm for atmospheric scattering [FASCAT], large area smoke screen [LASS], refraction [REFRAC], narrow beam scattering [NBSCAT], and band-integrated transmittances [BITS]); and

8. phase function and Mie code support modules.

The philosophy underlying the development of EOSAEL has been to include modules that give reasonably accurate results with the minimum in computer time for conditions that may be expected on the battlefield. The latest version of EOSAEL is available to approved users through the Test and Evaluation Community Network Bulletin Board System (TECNET). More information concerning EOSAEL may be found at the World Wide Web site URL address http://www.eosael.com.

7.4.2.3 Atmospheric Optical Turbulence

A model (CN2) [29] has been developed to allow a quantitative assessment of atmospheric optical turbulence. CN2 calculates vertical profiles of C_n^2 for near earth environments. The algorithm uses surface layer gradient assumptions applied to two levels of discrete vertical profile data to calculate the refractive index structure parameter. Model results can be obtained for unstable, stable, and near-neutral atmospheric conditions. The CN2 model has been benchmarked on data from the radiation and energy balance (REBAL) 1992 field study. The model will be added to EOSAEL in the near future.

7.5 Backgrounds

7.5.1 Smart Weapons Operability Enhancement

Terrain, vegetation, and weather effects present a complex, highly variable background for IR and Millimeter Wave (MMW) target seekers and IR viewers. This is especially true in the presence of snow and frozen ground. Captive flight tests are expensive and can account for only a limited range of conditions. DoD requires cost-effective methods for incorporating the complexities of the battlefield environment into training, planning, and weapon system development.

The physics-based Joint Test & Evaluation Smart Weapons Operability Enhancement (SWOE) is a synthetic scene generator. SWOE models can produce synthetic scenes for user-specified spectral regions in the visible, IR, and MMW regions. The SWOE thermal models consist of a soil/snow, vegetation, canopy, and a single 3-D tree model. The thermal models consider the exchange of energy via conduction, convection, radiation, evapotranspiration, and the mass flux of precipitation. The SWOE radiance models consider emitted, primary and secondary reflections, bi-directional effects, and atmospheric attenuation. The SWOE models are used to generate selected scenes for proposed generic validation procedures. SWOE also has an associated high spatial resolution measured data base, including meteorological information, taken diurnally over four seasons; the measured locations, Grayling, Michigan and Yuma, Arizona, represent European and SW Asian analogs.

CRREL researchers have integrated field testing, physics-based modeling, and image rendering techniques to generate IR and MMW synthetic scenes (see figures 3 and 4). Through the SWOE, a terabyte of IR and MMW validation images that span both winter and summer conditions have been assembled. An IR scene generation capability has been implemented and validated through the Office of the Secretary of Defense Joint Test and Evaluation Program. Physics-based MMW models of snow and soil processes have been coupled and distributed over test areas at high-spatial and temporal resolutions. Predicted signatures have been rendered into scenes which are comparable to measurements from captive flight tests. These maturing technologies can support training, planning, and weapon system development at a variety of levels. Applications include building all-weather databases for

Distributed Interactive Simulation applications, selecting conditions for live training, and constructing look-up tables of smart weapons performance under winter conditions.

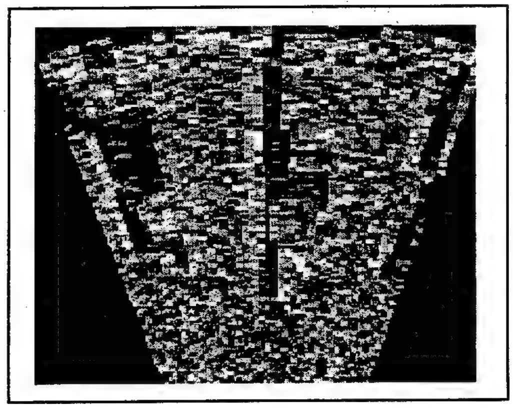


Figure 3. MMW scene

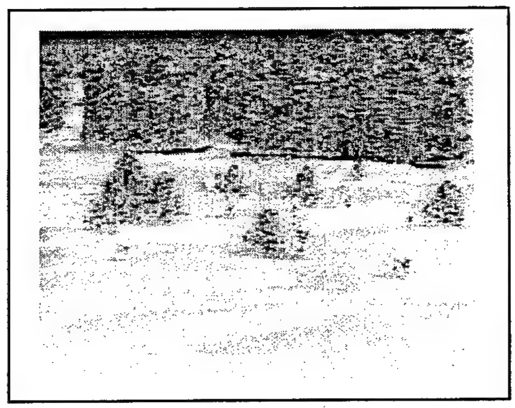


Figure 4. IR scene

7.5.2 Computer Generation of Realistic Environments with Atmospheres for Thermal Imagery with Optics and Noise

The ARL developed Computer Generation of Realistic Environments with Atmospheres for Thermal Imagery with Optics and Noise (CREATION) model is also a synthetic scene generator. CREATION is a 3-D, multispectral, high-resolution scene generation program, which has the capability to simulate IR and visible, static and dynamic synthetic images of many diverse real world environments. 3-D geometry inputs to CREATION start from digital maps obtained from the Defense Mapping Agency that have been interpolated to higher resolution of approximately 1 to 2 m. The associated high-resolution feature map is developed from high-resolution aerial pictures and road maps to define the location of trees, grass, roads, lakes, etc. The thermal signature of background components are predicted with the Interim Thermal Model

(developed under the SWOE program, using the Waterways Experiment Station's background prediction model and the SNTHERM model from CRREL); texture variations are also applied to the background components to enhance scene realism. 3-D target geometry can be placed into the 3-D background map with 6° of freedom. The target signatures are derived from either the PRISM or GTSIG signature prediction models. The sensor and target can be varied within these 6° of freedom to allow a multitude of viewing aspects. Atmospheric and sensor effects can also be applied to generate specific meteorological conditions and sensor system output.

7.6 Virtual Dirty Battlefield

The virtual dirty battlefield provides virtual smokes and obscurants modeling capability which can be integrated into synthetic scene generation of IR battlefield scenes and scenarios. It is being developed by Missile Research Development and Engineering Center, ARL, Night Vision Electronic Sensors Directive, U.S. Navy, and Industry to support all phases of laboratory and field-testing programs (primarily for imaging infrared sensors) where realistic dirty battlefield scenes and scenarios are required. It also has application to training, mission readiness (direct support testing) as well as mission rehearsal.

This capability utilizes the "emissive smokes" model created at Missile Research, Development, and Engineering Center and also makes use of the EOSAEL COMBIC model as well as the ARL developed statistics for battlefield-induced contaminants (STATBIC) model. These smoke and obscurant models represent natural and man-made aerosols, typically found in the dirty battlefield environment, and were selected as a result of a comprehensive market survey. Examples are shown in figures 5 and 6.

Figure 5. Battlefield scene

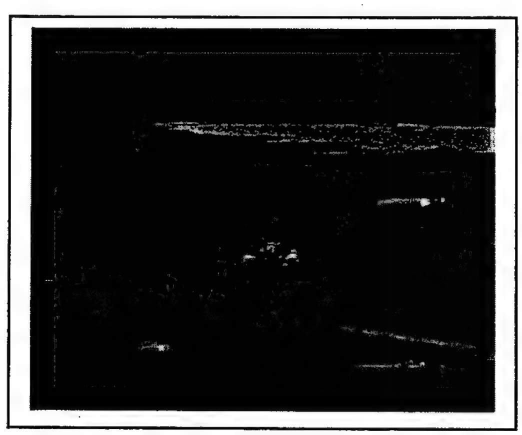
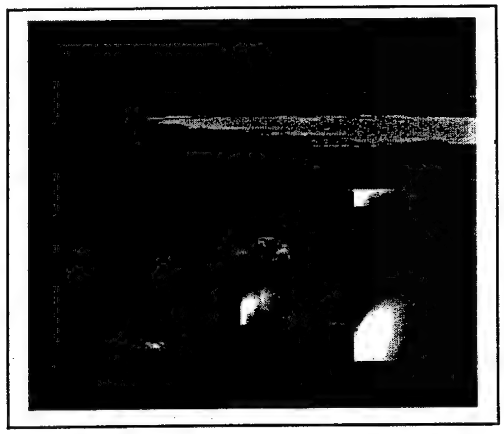


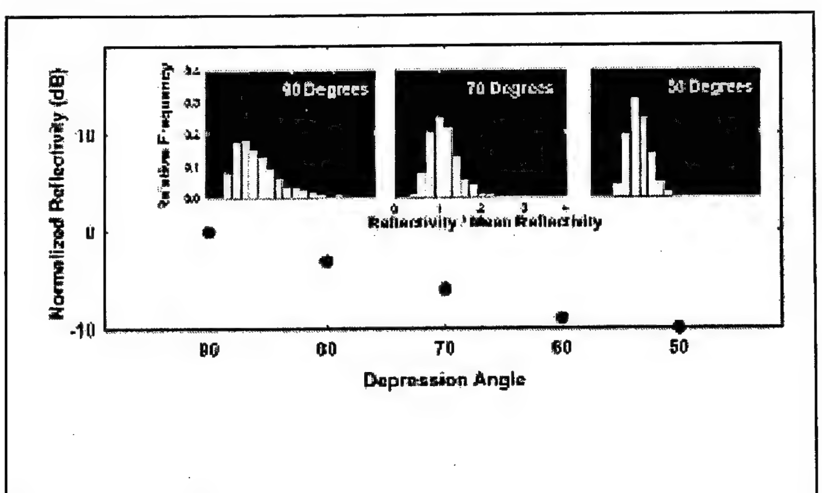
Figure 6. Battlefield scene with white phosphorus added.



7.7 Clutter Statistics of Wet Snow Cover Measured with a Full Maximum Continuous Wave Radar (32 to 35 GHz)

Snow-covered terrain represents a high-clutter environment for radar sensors. Because of the spatial and temporal variations in snow-cover properties, radars operating in a winter environment can encounter varying clutter statistics. Measurements have been initiated to determine the reflectivity characteristics of snow-covered terrain using a Full Maximum Continuous Wave (FMCW) radar operating at 32 to 35 GHz (see http://www.crrel.usace.army.mil/). The relatively high bandwidth allows resolution of the dominant scattering mechanisms in a snow cover and allows investigation of the effect of frequency averaging on clutter statistics. Initial analysis is limited to wet snow cover where surface scattering is the dominant scattering mechanism. Typical backscatter results from a wet snow cover are illustrated in figure 7.

Figure 7. Refractivity characteristics of a wet snow as a function of depression angle obtained with a FMCW radar operating at 32 to 36 GHz bandwidth.



For a wet snow cover, a 10-dB reduction in reflectivity can be expected as the radar depression angle decreases from 90 to 50°. The width of probability density function (PDF) normalized to the mean reflectivity will also decrease as the depression angle decreases. (The width of the normalized PDF will increase as the radar bandwidth decreases because of reduced frequency averaging.) For wet snow, the frequency-averaged PDFs were successfully fitted with Rayleigh statistics and successive convolutions of Rayleigh statistics. The analysis of clutter statistics from dry snow cover will be complicated by the volume scattering contributions from individual snow grains as well as the reflections from layers within the snow cover.

8.0 Priorities

The priorities for next year include the continuing education of users and developers in the methodologies, processes and procedures for DAE. This will be accomplished through documentation, presentations, and tutorials. The need for standard weather scenarios, the improvement of run times for physics-based models, and the inclusion of fast running weather impact algorithms for aggregated simulations are high priorities for the DAE category. Other priorities in the DAE category are presented in table 3.

Table 3: DAE priorities in the near-, mid-, and far-time frame

FY	Projects
Near	Weather simulation (WARSIM) weather effects
Near	Acoustics for COMBAT XXI
Near	Icing prediction model
	Areas
Mid	Emissive smokes
Mid	Urban "canyon" winds
Mid	Weather for embedded training
Mid	Weather integration into joint common database (JCDB)/M&S
Mid	Remote Sensing Analysis Models
Mid	Forest Effects on Acoustic Sensors
Far	Atmospheric effects for military operation in urban terrain (MOUT)

9.0 Conclusions

The environmental community is encouraged to participate in the AMSO standard-category DAE area. The DAE category is always desirous of outside opinions and people who wish to contribute their time. Participation is particularly encouraged via the DAE reflector and at the U.S. Army M&S Standards Workshop which meets annually in the spring. Further information can be obtained from the DAE home page at http://www.amso.army.mil/sp-div/dyn-env.htm or directly from the standards category coordinator via email to rshirkey@arl.mil.

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Acronyms and Abbreviations

2 D	two dimensional
3 D	three dimensional
4 D	four dimensional
3DSE	Three-Dimensional Static Environments and Initialization
ABCS	Army Battle Command System
ABCSIM	Atmospheric Biological/Chemical Simulation
ABFA	Acoustic Battlefield Aid
AIRFLOS	Airflow Simulation
AIM	Atmospheric Illumination Module
AIRSIM	Atmospheric Simulation
AMIP	Army Model Improvement Plan
AMSEC	Army Modeling and Simulation Executive Committee
AMSO	Army Modeling and Simulation Office
ARL	U.S. Army Research Laboratory
ATMOS	Atmospheric Optical Turbulence Model
BASE	Battlefield Acoustic Sensor Evaluator
BASIS	Battlefield Acoustic Sensor Integration System
BFA	Battlefield Functional Area
BFM	Battlescale Forecast Model
BITS	band integrated transmittances
BLIRB	Boundary Layer Illumination and Radiative Balance Model
CASTFOREM	Combined Arms and Support Taskforce Evaluation Model
C4I	Command, Control, Communications, Computers, Intelligence
CCSL	Coupled Surface Layer
CLIMAT	climatology

COAMPS	Coupled Ocean Atmosphere Model Prediction System
COMBIC	Combine Obscuration Model for Battlefield Induced Contaminants
COPTER	helicopter
CREATION	computer generation of realistic environments with atmospheres for thermal imagery with optics and noise
CRREL	Cold Regions Research Engineering Laboratory
CSSM	Cloud Scene Simulation Model
D2PC	Two-Dimensional Transport and Diffusion for Personal Computers
DAE	Dynamic Atmospheric Environments
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
E2DIS	Environmental Effects for Distributed Interactive Simulation
EOSAEL	Electro-Optical Systems Atmospheric Effects Library
EOTDA	Electro-Optical Tactical Decision Aid
FASCAT	fast algorithm for atmospheres scattering
FFP	Fast-Field Program
FITTE	fire-induced transmission and turbulence effects
FMCW	Full Maximum Continuous Wave
GFPE	Green's Function Parabolic Equation
GRNADE	grenade
HLA	High-Level Architecture
HRW	High Resolution Wind
ILUMA	illumination
IMETS	Integrated Meteorological System
IR	infrared
IWEDA	Integrated Weather Effects Decision Aid

JCDB	Joint Common Database
KWIK	cross wind integrated concentration
LASS	large area smoke screen
LES	Large Eddy Simulation
LOWTRAN	low resolution transmission
LZTRAN	laser transmission
M&S	Modeling and Simulation
MM5	Fifth-Generation National Center of Atmospheric Research/Penn State Mesoscale Model
MODTRAN	Moderate Resolution Transmission
MOUT	military operation in urban terrain
MPLUME	missile plume
NBSCAT	narrow beam scattering
NGIC	National Ground Intelligence Center
NMMW	near-millimeter wave
NVESD	Night Vision and Electronic Sensors Directorate
NOVAE	non-linear vaporization and breakdown effects
OVRCST	overcast
P&T	Policy and Technology
PDF	Probability Density Function
PIXELMOD	pixel modification
RAMS	Regional Atmospheric Modeling System
REBAL	Radiation and Energy Balance
REFRAC	refraction
SCAFFIP	Scanning Fast-Field Program
SCAPE	Scanning Parabolic Equation
SCC	Standards Category Coordinators
SCIPUFF	Second Order Closure Integrated PUFF

SGR	sky-to-ground ratio
SNTHERM	snow thermal
STATBIC	statistics for battlefield-induced contaminants
STOW-SE	synthetic theater of war – synthetic environments
SWOE	smart weapons operability enhancement
SWOETHERM	smart weapons operability enhancement thermal
T&D	transport and diffusion
TADSIM	Transport And Diffusion Simulator
TAMIP	Target Acquisition Modeling Improvement Program
TARGAC	target acquisition
TAWS	Target Acquisition Weather Software
TAOS	Total Atmosphere Ocean Server
TDA	tactical decision aids
TECNET	Test and Evaluation Community Network Bulletin Board System
TRAC	U.S. Army Training and Doctrine Command Analysis Center
TRADOC	U.S. Army Training and Doctrine Command
UVTRAN	ultra-violet transmission
VIEW	view point
VLSTRACK	vapor liquid solid tracking
WARSIM	War Fighter's Simulation
WAVES	Weather And Visualization Effects for Simulations
WG	Working Group
XSCALE	scaled transmission

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